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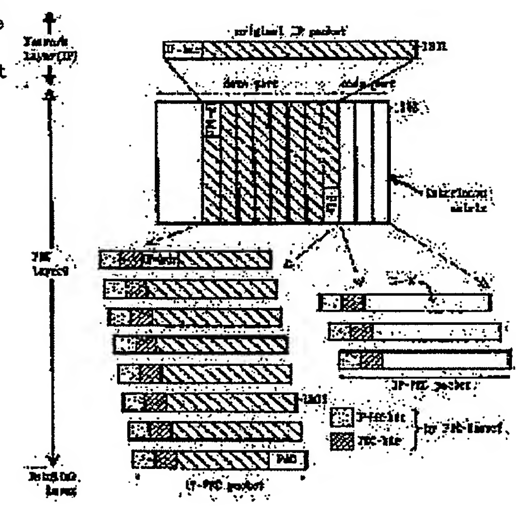
(54) CODE TRANSMISSION METHOD, TRANSMITTER, RECEIVER AND COMMUNICATION SYSTEM

(57)Abstract:
PROBLEM TO BE SOLVED: To realize a flexible error correction system by generating a transmitter side syndrome information to be sent and transmitting an information packet including information to be sent and a redundant packet, including the generated transmitter side syndrome as a redundant part of an error correction code.
SOLUTION: An FEC layer receives an IP packet from an IP layer and writes an original IP packet 1301 to a memory buffer area of an interleave matrix 1302 together with a packet header. The write is conducted by writing data in a longitudinal direction of the interleave matrix 1302 to set the packet to be a variable size. Error correction coding results are calculated for each lateral row and coding data which is the result of calculation are written. The maximum lateral length depends on the size of symbols used for error correction and are equivalent to a total maximum number of longitudinal columns of data and codes. The receiver side conducts required error correction, based on the information from the transmitter side to conduct reliable communication.



Forward Error Correction for QoS-Reserved Internet Broadcasting

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We examined a method of reducing an error rate of data with Forward Error Correcting (FEC) on QoS-reserved Internet. We propose a method that can change the strength of FEC in accordance with an error rate required by application programs. We also compared a use efficiency of a network bandwidth of a method of reducing a packet loss rate by routers using a queuing method called "Comfortable Service" with a method of reducing a data error rate by FEC.

1. Preface

In an environment wherein voice/motion picture data are transmitted in multicast, and are reproduced at a receiving host simultaneously with receiving the data, Forward Error Correcting (FEC) is effective to reduce data errors caused by packet loss and others.

In the present paper, it is assumed that a bandwidth, delay, and a packet loss rate of a path of a network that carries the multicast are guaranteed by QoS reservation. It is possible to make the packet loss rate near zero; however, it is impossible to make it zero. Further, a study shows that designing a router that reserves QoS is facilitated by allowing a certain packet loss.

At Section 2, the environment considered in this paper is described in detail, in which environment, voice/motion pictures are distributed on the Internet. In Section 3, problems with

conventional studies are discussed. In Section 4, a transmission/reception library employing FEC coding is proposed, in the premise that a QoS-reserved path is used. In Section 5, improvements in network use efficiency are compared between a method of reducing the packet loss rate by the router when a queuing method, proposed as Comfortable service (CS), is used and a method of correcting data errors by FEC. In Section 6, a library that is actually mounted is described and measured performances are discussed.

2. Internet broadcast

Internet broadcast provides data such as voice and motion pictures using IP multicast.

If there is an error, a disruption is generated to the voice and the images. Nevertheless, if the disruption is within an allowable range for the users, the error does not have to be corrected.

If the disruption is beyond the allowable range, it is desirable that the data be corrected. In an application where the received data are immediately reproduced, retransmission of the data for correction can be too late for the reproduction. Accordingly, the data are corrected using FEC.

Here in the present paper, data errors are generated only by a packet loss(*), that is, packets received by the receiving host are considered data error free.

(*)Packet loss is generated when router queue is disturbed, and when an error is generated in the transmission path. Packets that contain an error generated in the transmission path are discarded by the router.

3. Conventional studies

3.1 Method using a FEC exclusive flow:

A packet format when attaching a FEC code

to a RTP (Real-Time Transport Protocol) packet[4] is proposed by RFC2733[3]. According to the proposal, the RTP packet for FEC is generated from a normal RTP packet, and both packets are transmitted by different flows. Since the packet for FEC is transmitted by a different flow, it is expected that an application that does not correspond to FEC can be properly operated.

3.2 Method using fragment process of IP packet:

A method of simultaneously transmitting the packet for FEC and a fragment is proposed[5] by expanding a packet fragment process[1] of IPv6. According to this method, a transmitting application can transmit a lump of data of a great magnitude without minding the packet for FEC, and MTU size. If the data are greater than the MTU size, the data are divided into two or more IP packets by the fragment process. According to the proposed method, a process of attaching the packet for FEC simultaneously with the fragment process is added.

3.3 Problems with conventional studies

The method proposed by 3.1 uses parity to the FEC code. Reed Solomon coding that has higher error correction capability cannot be used.

Further, both the methods in 3.1 and 3.2 have problems in that

- Data volume after attaching FEC is uncertain, and
- Final error rate is uncertain.

Since the present study considers a method of reserving a bandwidth of a path, through which data are carried, an application has to know in advance an incremental amount of the data that flows through the network when FEC is used.

Further, according to conventional studies,

the error rate may be certainly decreased; however, FEC is used without aiming at a target error rate. It should be important that FEC is used to attain an error rate that is required by the user or applications.

The present paper proposes a method to solve these problems.

4. Forward error correction in QoS-reserved path

4.1 Forward error correction with Reed Solomon coding

As FEC coding, Reed Solomon (RS) coding is adopted. According to RS coding, (n-k) bits of errors can be corrected if bit error position is known, where n is a code word length, and k is an information bit length.

Since data errors occur only due to packet loss according to the present study, error correction codes are computed from data in the same positions of media packets that store original data, and are stored in the same positions of FEC packets (packets for FEC) as shown in Fig. 1.

Fig. 1: Attaching FEC packet by RS coding

To k media packets n-k FEC packets are attached, and a total of n packets are transmitted. In this case, out of the n packets that are transmitted, if any less than (n-k) packets are not received, correct data can be acquired by error correction.

4.2 Data error rate

Since the path for multicast is QoS reserved, the bandwidth, delay, and packet loss rate are known.

The Internet broadcast may provide

services of different qualities such as a voice broadcast at a telephone level quality, and a high quality motion picture like a movie. It is conceivable that required data error rates are different for each of the services. Then, the strength of FEC coding is made variable according to a target data error rate.

As pointed out in Section 3, what is important to an application program is not simply reducing the error rage, but reducing the error rate less than a certain value. The proposal of the present paper is characterized in that the strength of the error correction coding is adjusted according to the data error rate required by the application program.

In the following, a method of determining the strength of RS coding corresponding to the target error rate is described.

According to the error correction coding of the proposal, if more than (n-k) packets out of n packets are lost, correct data cannot be acquired. A probability E of the data being not correctable is expressed by the following Formula (1).

$$E=\sum_{i=n-k+1}^{n} {}_nC_i e^i (1-e)^{n-i}$$

Here, e represents a packet loss rate between transmitting and receiving hosts.

Since e and k are known, E is determined by a value of n. By calculating E for various n, n that achieves the target error rate can be obtained. The value n determines the strength of RS coding.

Further, the data volume that is to be transmitted is determined by n; accordingly, the application program can determine a bandwidth required for reservation when reserving QoS.

5. Comparison of network bandwidth use

efficiency

According to Comfortable Service (CS), a part of a bandwidth that a router can transfer is used for QoS reservation. Here, a ratio of the bandwidth used by the QoS reservation to the whole bandwidth is expressed by b. It is known that, in CS, a packet loss rate at the router is determined depending on the queue length of the router and b. By reducing b, the packet loss rate can be reduced; however, the bandwidth that can be QoS reserved is reduced.

In the case wherein the data error rate is reduced by FEC, since FEC packets are transmitted other than the media packets, a ratio of real data to the whole of the available bandwidth is reduced.

Here, a network use efficiency when the packet loss rate is reduced by reducing b is compared with the same when the packet loss rate is reduced by FEC.

Fig. 2 shows two graphs wherein packet loss rates for b=0.5, 0.6, 0.7, 0.8, and 0.9 are illustrated when the router queue length is 25.

The vertical axis of the graph represents the ratio of the bandwidth available to transferring real data to the whole bandwidth. The horizontal axis represents the packet loss rate after passing through 100 steps of routers (the right hand end represents the smallest loss rate).

Each line in the graphs represents transition of the packet loss rate vs. the bandwidth available ratio for different values of b. The left hand end of each line represents when FEC is not used; and the right hand end of each line represents when FEC is used for reducing the error rate.

According to FEC coding proposed by the present paper, FEC is used to the more packets, the higher the bandwidth use efficiency becomes. Fig. 2

(a) shows case wherein the number of packets to which FEC is applied is 10. Fig. 2 (b) shows the case wherein the number of packets to which FEC is applied is 100.

In real time communications, it is conceivable that the number of packets to which FEC is attached at one time is about 10 for a lower quality motion picture, and about 100 for a higher quality motion picture.

From Fig. 2 (b), where the number of packets is great, the error rate can be reduced with nearly no reduction in the bandwidth use ratio due to attaching FEC.

From Fig. 2 (a), where the number of packets is small, the bandwidth use efficiency is somewhat reduced. In order to obtain an error rate of about 10^{-10}, the bandwidth use efficiency has to be reduced to about 0.5 if FEC is not used; however, if FEC is used while b is set at 0.7 or 0.8, the bandwidth use efficiency can be increased to about 0.6.

From the results described above, rather than the method of reducing the packet loss rate only by the CS-compliant router, simultaneously using the method of reducing the data error rate by FEC raises the network use efficiency.

6. Actual mounting

A library for attaching FEC code using RS coding was mounted.

A transmission applicable program provides three parameters, namely, {the number of packets processed in one shot, data error rate of network, desired error rate}. Then, n that provides the "desired error rate" is obtained from Formula (1), the library on the transmission side is initialized, and n is provided to the application. The

application is to use this n when reserving a bandwidth.

Once the library is initialized, when the application provides real data to FEC library, FEC packets are automatically attached and transmitted to the network.

At the receiving host, a parameter expressing the strength of FEC coding, and the like are provided to the library on the receiving side, then a receiving buffer and the like are initialized, and receiving is started.

When the application requests reading to the library, data are taken out from the buffer. At this time, if there is a packet loss, error correction is automatically performed.

Times required to attach FEC coding at the library, and to correct errors were measured. (*)

(*) For measurement, a machine with Pentium III 600 MHz was used.

The measurements were made by attaching FEC packets to 10 packets of 1280 bytes, when a packet loss rate of 10^{-3} was to be reduced to 10^{-9}. In this case, 3 FEC packets were attached to 10 media packets. The data volume was chosen as a compressed image of about 320x240.

At this time, a calculation time required to generate the FEC packets was less than 0.005 s. A time required for calculation of error correction was less than 0.14 s when 3 packets were lost, less than 0.11 s when 2 packets were lost, and less than 0.09 s when one packet was lost.

If an environment (**) wherein the image data (10 media packets + 3 FEC packets) are transmitted at 30 frames/min. is considered, since the error correction time is long, it is difficult to display 30 frames a minute if packet loss occurs frequently. However, the packet loss of the network

is presumed to be 10^{-3}, error correction actually takes place once every 2.5 s or more. Theoretically, it is possible to carry out data error correction for 30 frames/min. under the environment of the experiment.

(**) In this environment, if the packet loss rate is 10^{-3}, and if no forward error correction is performed, 1/10 of a whole image may not be correctly decoded once every 2.5 s. If the error rate is reduced to 10^{-9}, an error occurs once every tens of days.

7. Conclusion

In the present paper, discussion and proposal were made about the forward error correction in the path that is QoS-reserved.

The library for automatically setting the strength of the error correction coding according to the error rate required by the application program was proposed and actually mounted. Since the incremental data volume due to error correction coding is known, the bandwidth to reserve becomes known.

Further, the method of reducing the packet loss rate at the router and the method of reducing the data error rate by the error correction were compared. The error correction coding was able to remarkably reduce the error rate with a slight increase in the data volume, and the network use efficiency attained was higher than by reducing the error rate by the router in many cases.

The library that was actually mounted was introduced, and process times were measured. It was possible to reproduce a motion picture on a real time basis with the data used in the experiments. As the data volume increases, the process by the actually used machine may be delayed; however, the

delay can be solved by enhancing the processing capacity of the computer, and optimizing calculation routines.

References

[Almost all in English. Not translated.]

[End]